The Periodic Table and Periodic Trends

IB Chemistry

Topic 03 - Periodicity

Periodic Table

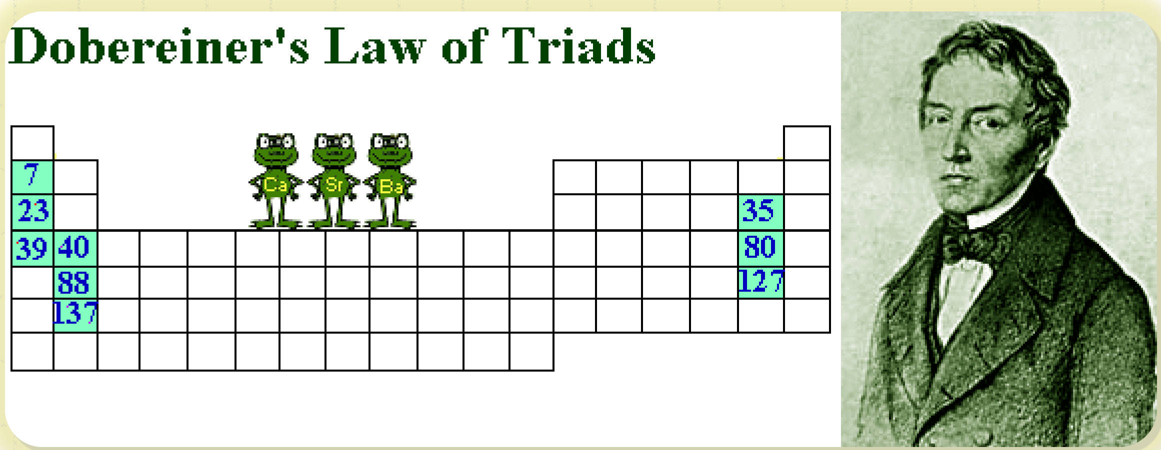
- **The development of the periodic table brought a system of order to what was otherwise an collection of thousands of pieces of information.**
- **The periodic table is a milestone in the development of modern chemistry. It not only brought order to the elements but it also enabled scientists to predict the existence of elements that had not yet been discovered .**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.409	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Uub** (285)	113 **Uut** (284)	114 **Uuq** (289)	115 **Uup** (288)			

* Lanthanide series	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
# Actinide series	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Early Attempts to Classify Elements

- Dobreiner’s Triads (1827)
  - Classified elements in sets of three having similar properties.
  - Found that the properties of the middle element were approximately an average of the other two elements in the triad.



Newland’s Octaves -1863

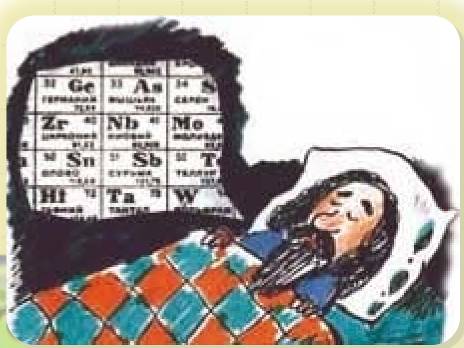
- John Newland attempt to classify 62 known elements
- He observed that when ordered by Atomic Mass, there was a an observable repetition every eighth element
- Tried to correlate the trends with musical scales, was ridiculed, and eventually awarded for his findings.

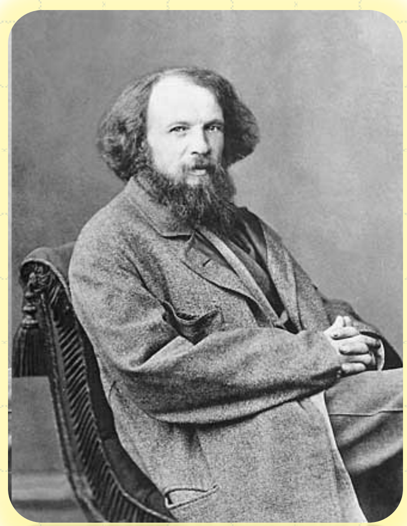
Dmitri Mendeleev

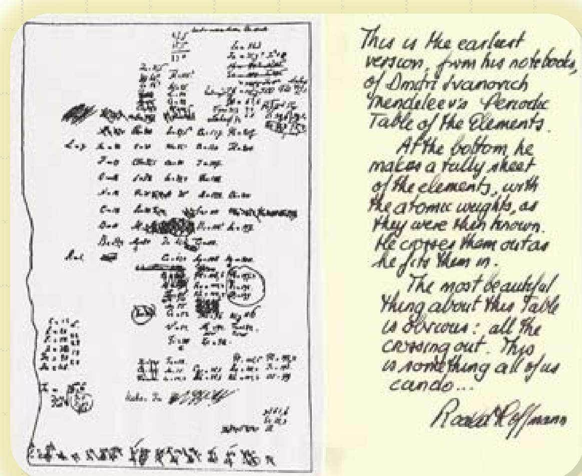
- Dmitri Mendeleev is credited with creating the modern periodic table of the elements.
- He gets the credit because he not only arranged the atoms, but he also made predictions based on his arrangements His predictions were later shown to be quite accurate.

Mendeleev's Periodic Table

- Mendeleev organized all of the elements into one comprehensive table.
- Elements were arranged in order of increasing mass.
- Elements with similar properties were placed in the same row.







Mendeleev's Periodic Table

Tabelle II.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Mendeleev left some blank spaces in his periodic table. At the time the elements gallium and germanium were not known. He predicted their discovery and estimated their properties.

PERIODS -

SIMILARITIES: THE NUMBER OF OUTER ELECTRON SHELLS.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

GROUPS –

Similarities: The number of electrons in the outer shell. Common reactivity, bonding, chemical and physical properties.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

METALIC PROPERTIES

SIMILARITIES: AN ELEMENTS RELATIVE ABILITY TO CONDUCT ENERGY IN THE FORM OF HEAT OR ELECTRICITY.

NON METALS

THE "STAIR"

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

METALS

METALOIDS

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Alkali Metals
Alkaline Earths
Transition Metals
Metaloids
Non-metals
Halogens
Weak/Poor Metals
Noble Gases
Lanthanides
Actinides
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

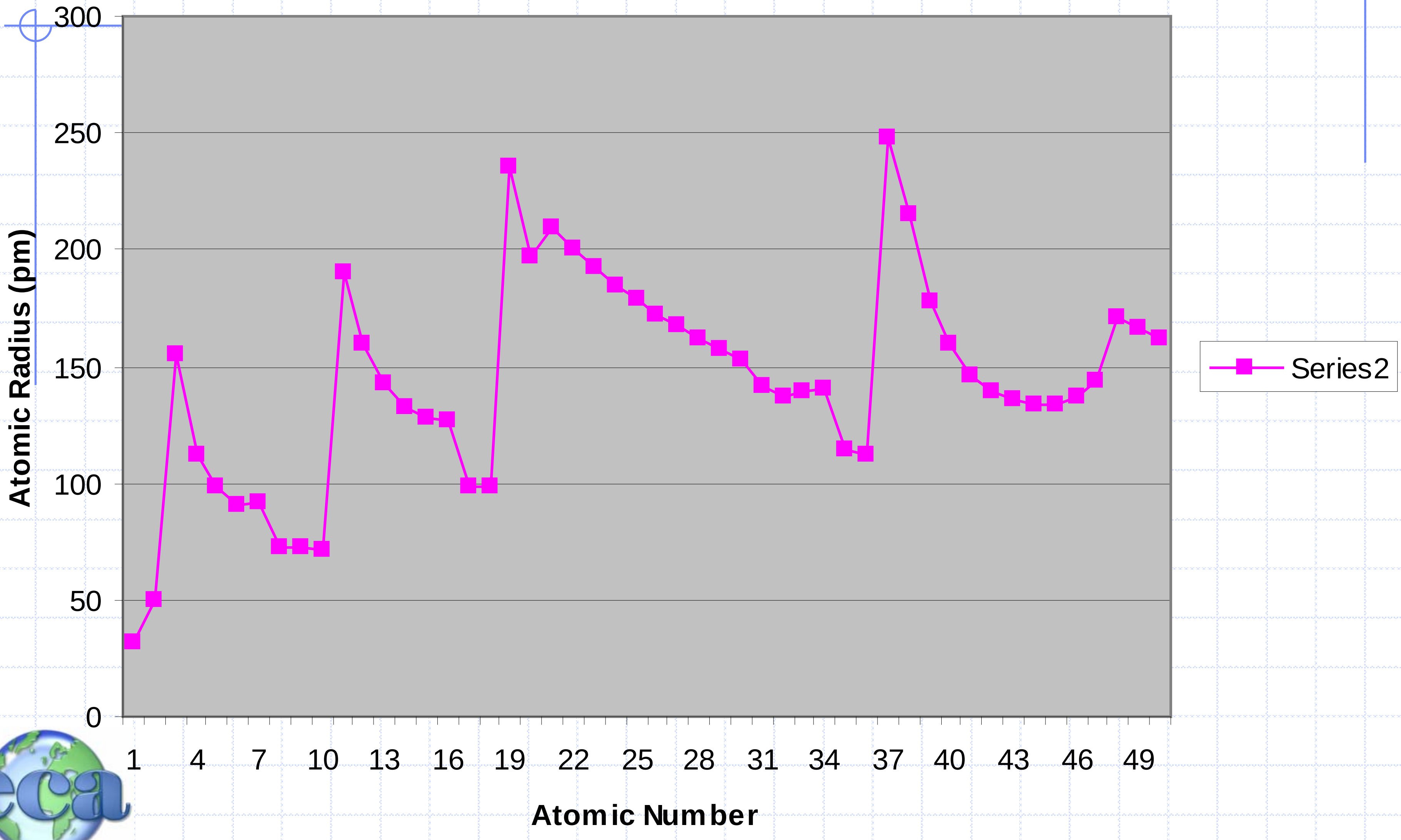
Periodic Law

- When the elements are arranged in order of increasing atomic number, there is a periodic repetition of their physical and chemical properties

Atomic Radius

A measure of the distance from the center of the nucleus to the outer-most electron (Bottom Left, Fr has the largest Atomic Radius)

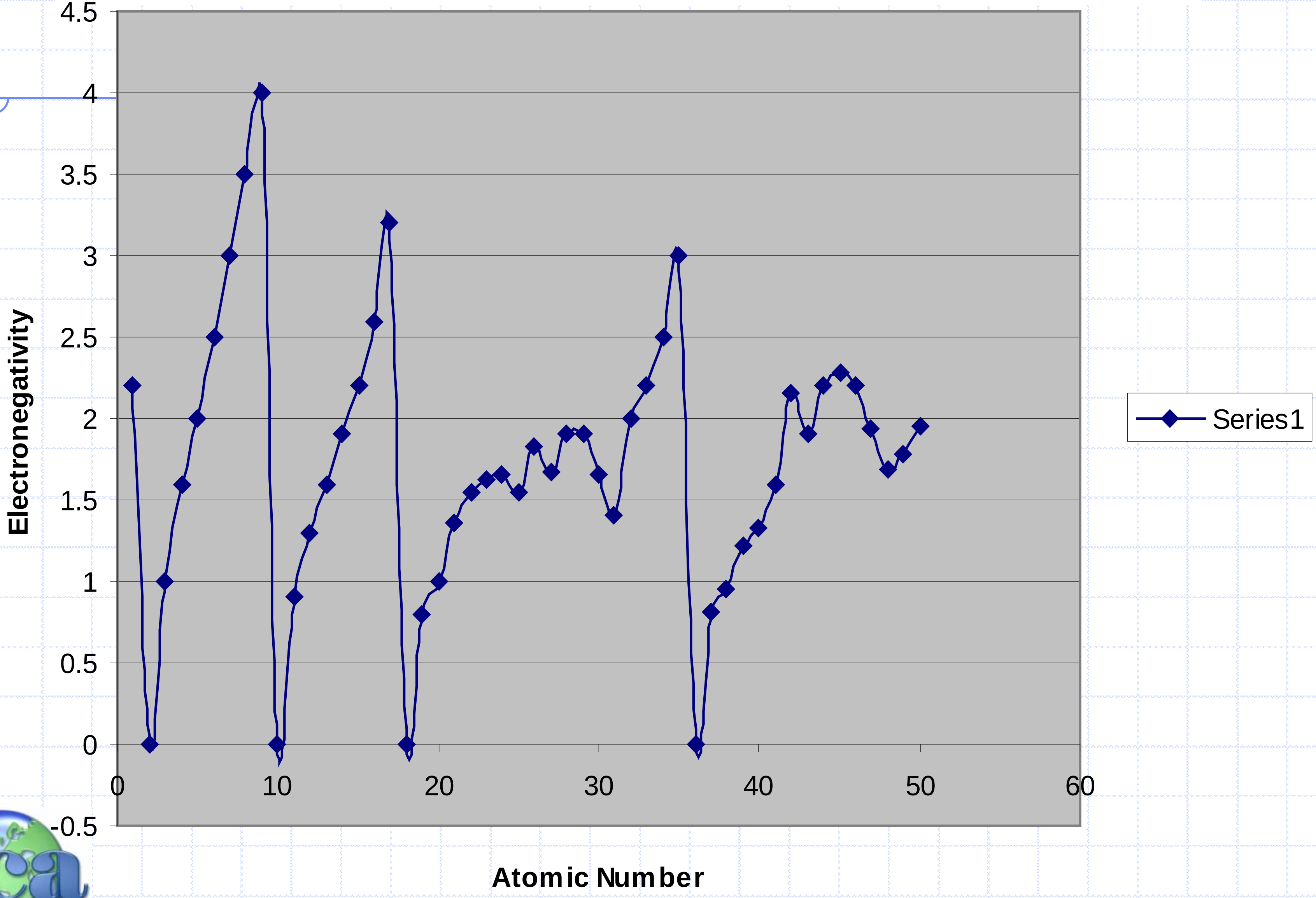
Atomic Radius Trend



Electronegativity

<u>An atoms ability or affinity to gain another electron</u>. Trend (Top right, excluding the noble gasses, F is the most electronegative element)

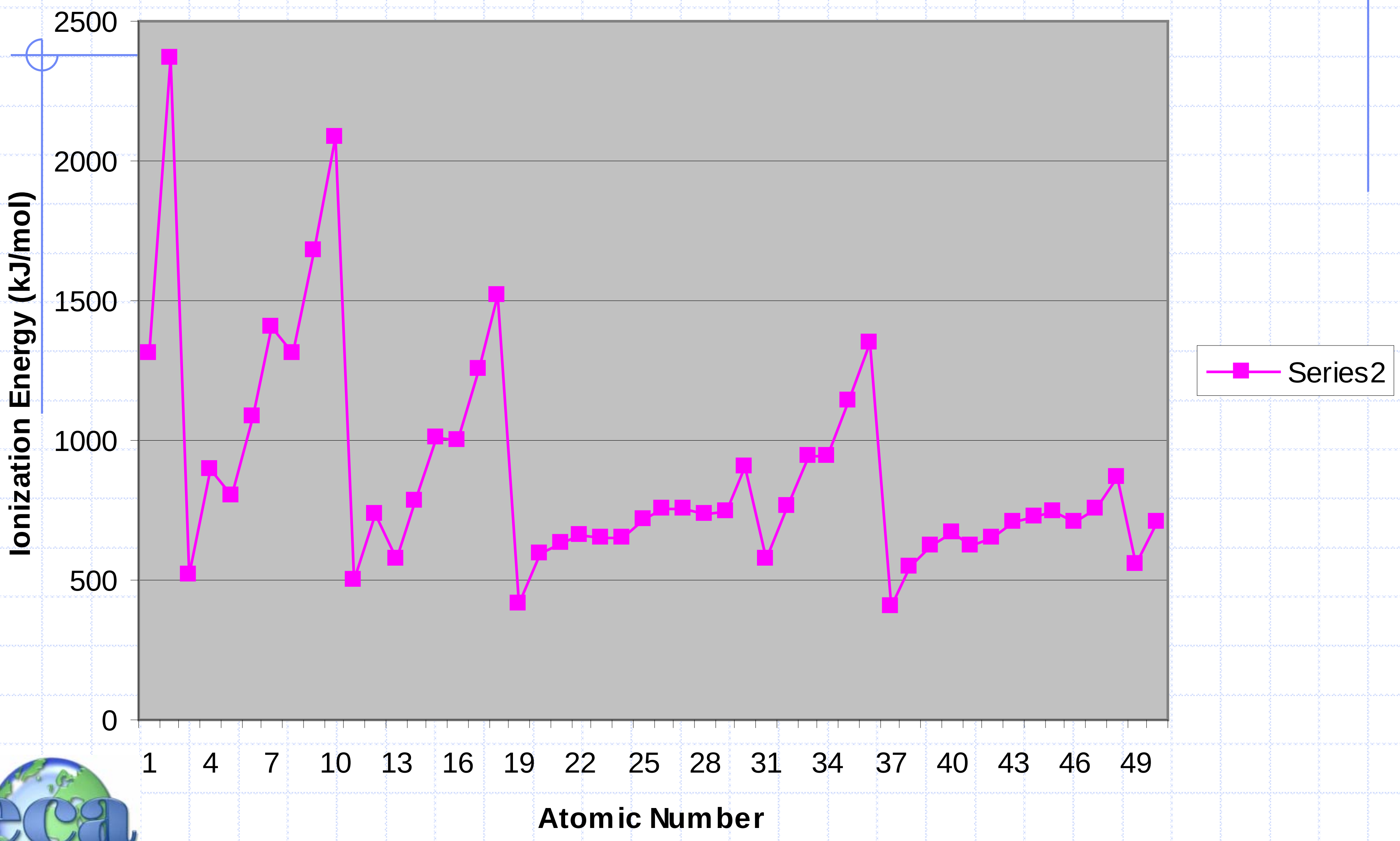
Electronegativity Trend



Ionization Energy

The energy required to lose the outer-most electron from an element. (Top right, He has the greatest ionization energy)

Ionization Energy Trend



Reactivity

An atoms general ability to undergo a chemical reaction. The Alkali Metals are the most electronegative family/group. (Bottom Left, Fr is the most reactive)

Reactivity

- Highly reactive – readily participates in chemical reactions

- Unreactive – does not readily participate in chemical reactions

http://teachertube.com/viewVideo.php?video_id=41344&title=Alkali_Metals___Brainiac

Trends of the Periodic Table

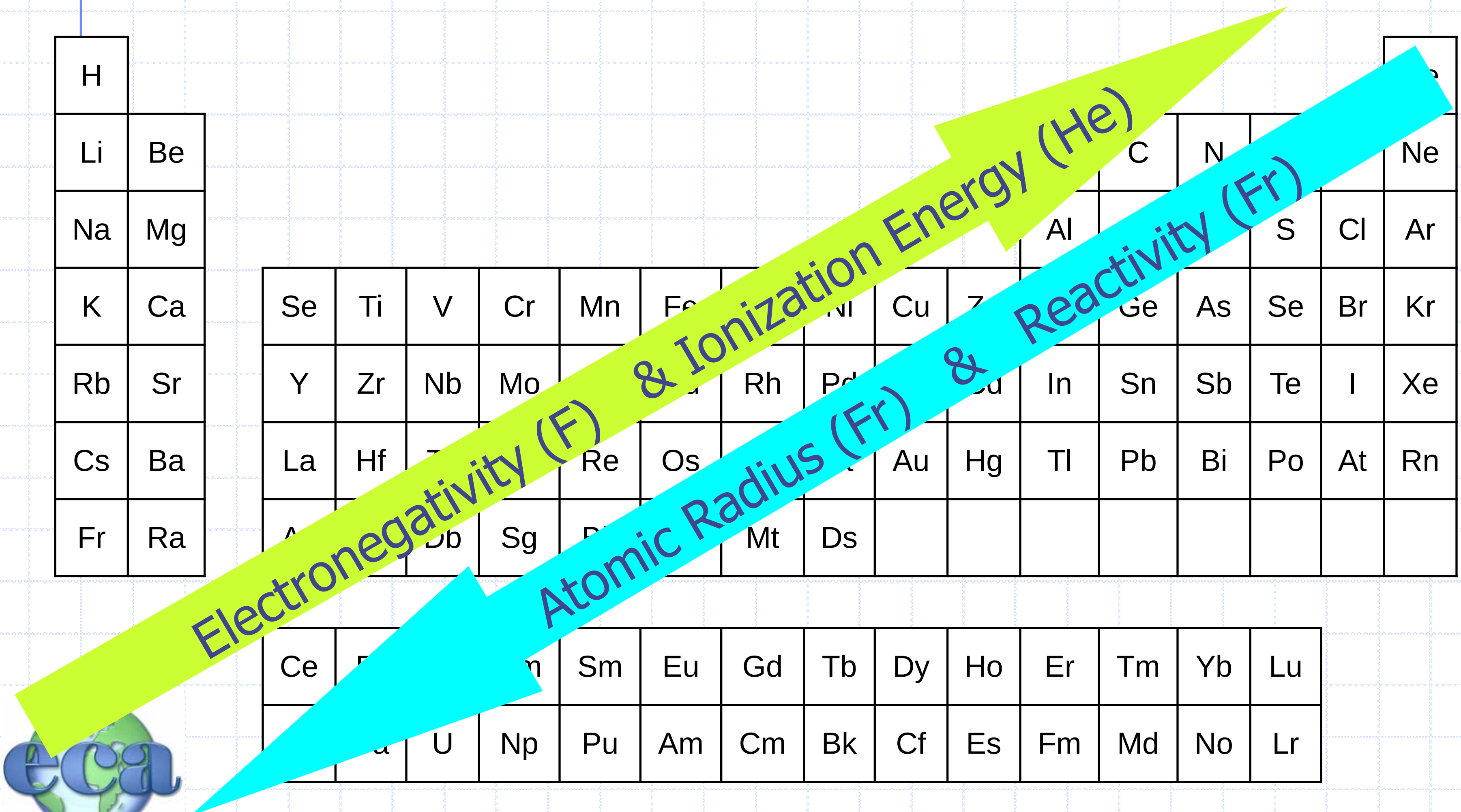
Atomic Radius: A measure of the distance from the center of the nucleus to the outer-most electron

Electronegativity: An atoms ability or affinity to gain another electron.

Ionization Energy: The energy required to lose the outer-most electron from an element.

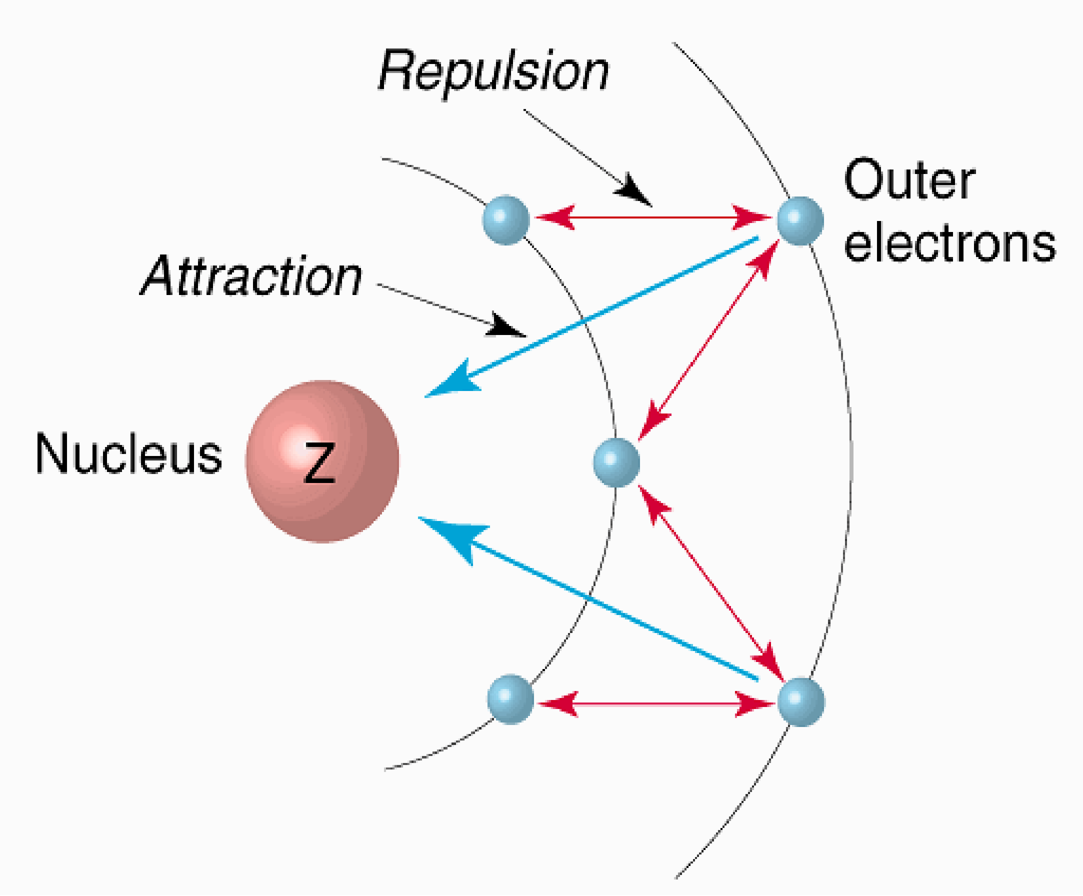
Reactivity: An atoms general ability to undergo a chemical reaction.

4 MAJOR TRENDS:
TOP RIGHT OR BOTTOM LEFT?

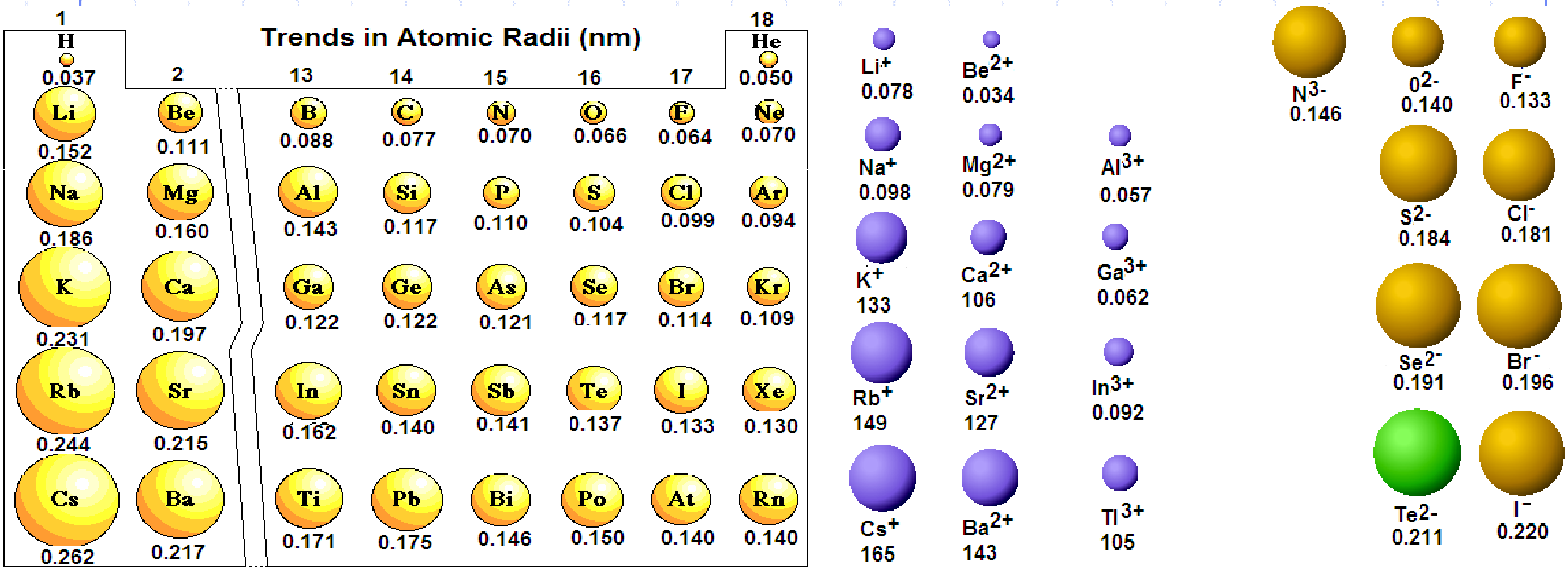


The Electron Shielding Effect

- Electrons between the nucleus and the valence electrons repel each other making the atom larger, **affecting the atomic radius**

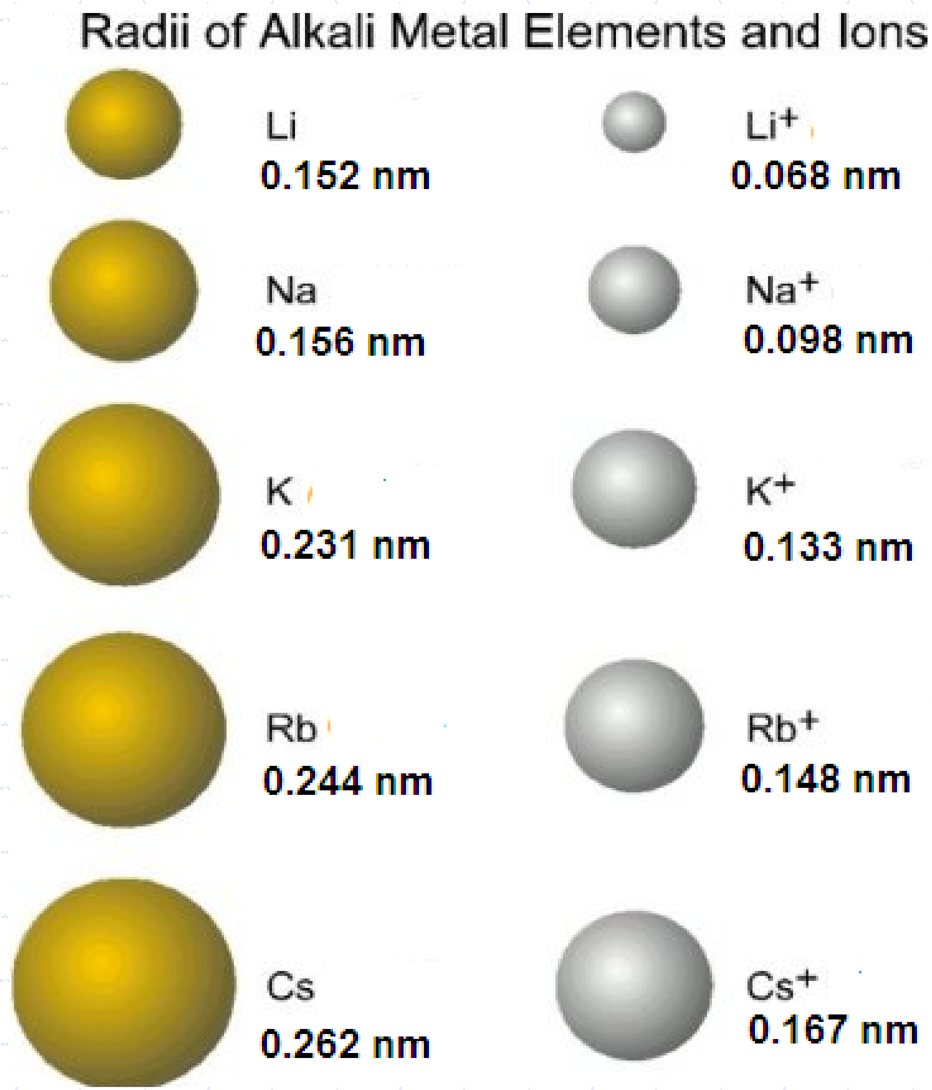


Atomic Radius of Neutral and Charged Species



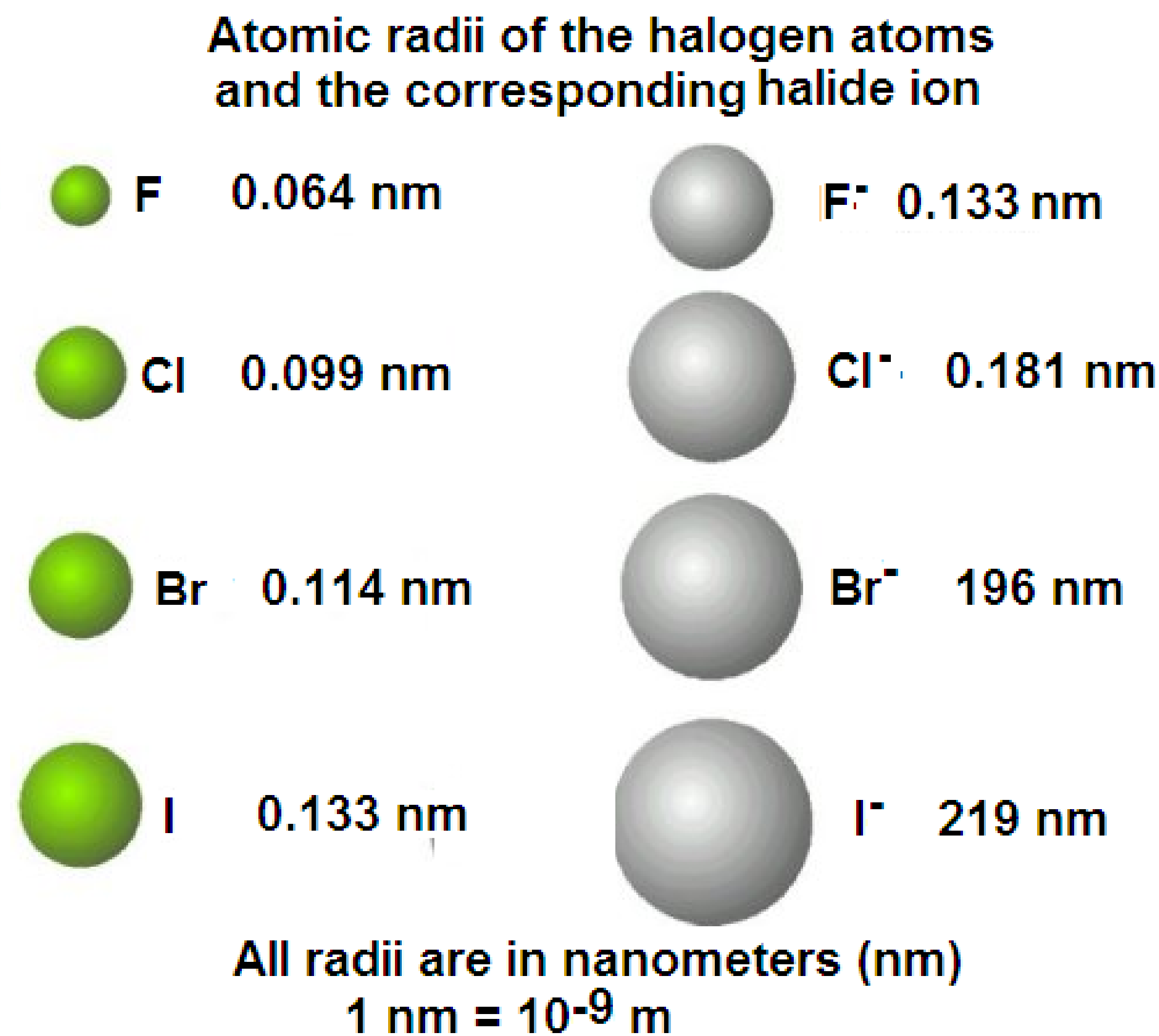
Ionic Radius for Cations

Boosts the **effective nuclear charge!**



Ionic Radii for Anions

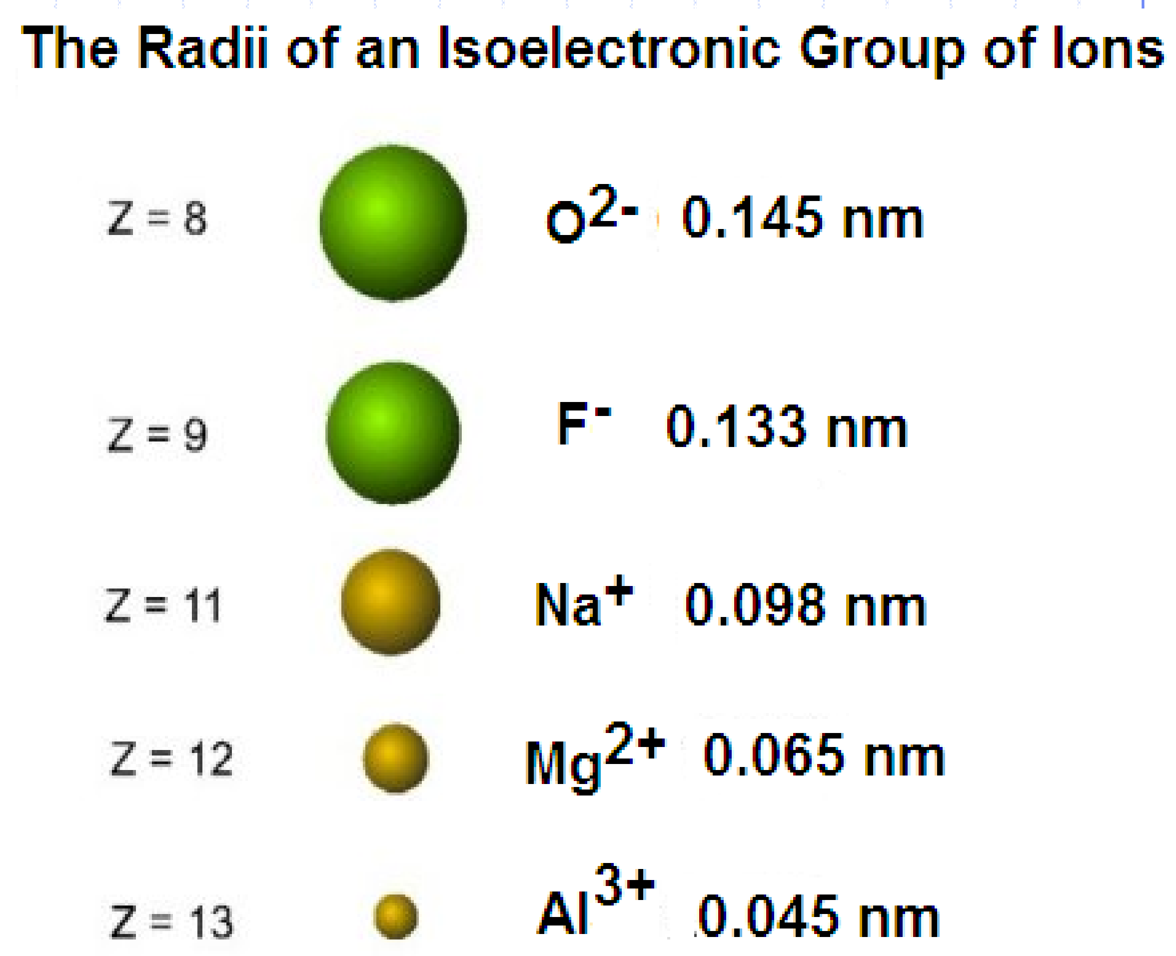
Lowers the **effective nuclear charge**



Ionic Radius for an Isoelectronic Group

Isoelectronic ions have the same number of electrons.

The more negative an ion i the larger it is and vice versa.

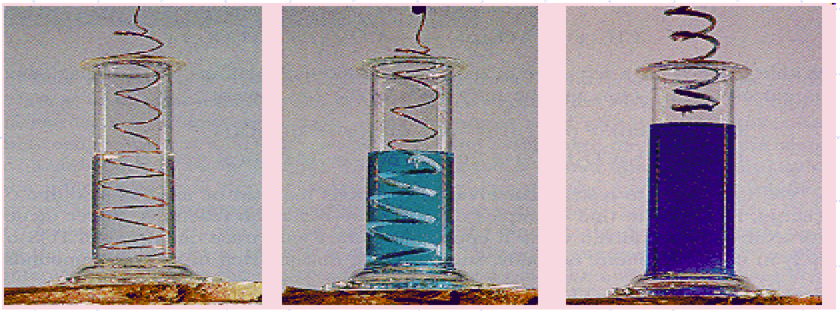


Colorful Transition Metals

- Complex ion information is interesting, but SL students will not be asked to justify the color of transition metal compounds in solution.

Complex Ions

- The ions of the d block and the lower p block have unfilled d or p orbitals.
- These orbitals can accept electrons either an ion or polar molecule, to form a dative bond. This attraction results in the formation of a complex ion.
- A complex ion is made up of two or more ions or polar molecules joined together.
- The molecules or ions that surround the metal ion donating the electrons to form the complex ion are called ligands.



Complex Ions

- Compounds that are formed with complex ions are called coordination compounds
- *Common ligands*

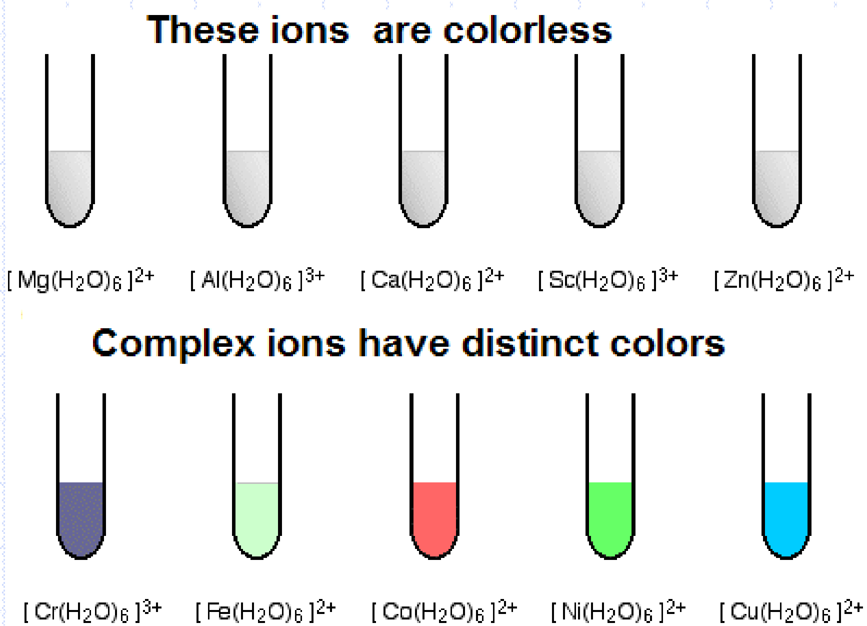
Water Ammonia Chloride Cyanide

- Complex ions usually have either 4 or 6 ligands.

$K_3Fe(CN)_6$ $Cu(NH_3)_4^{2+}$

Complex Ions

- The formation of complex ions stabilizes the oxidations states of the metal ion and they also affect the solubility of the complex ion.



The formation of a complex ion often has a major effect on the color of the solution of a metal ion.

The D-Block Colored Compounds

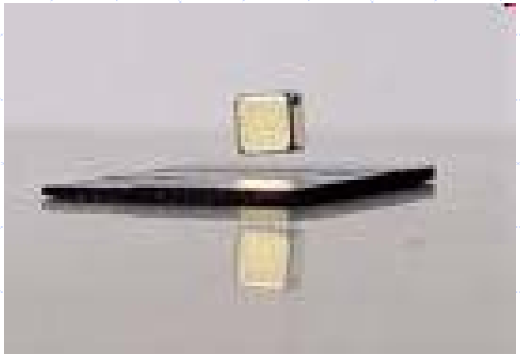
- In an isolated atom all of the d sublevel electrons have the same energy.
- When an atom is surrounded by charged ions or polar molecules, the electric field from these ions or molecules has a unequal effect on the energies of the various d orbitals and d electrons.
- The colors of the ions and complex ions of d block elements depends on a variety of factors including:
  - The particular element
  - The oxidation state
  - The kind of ligands bound to the element

Various oxidation states of Nickel (II)

Colors in the D Block

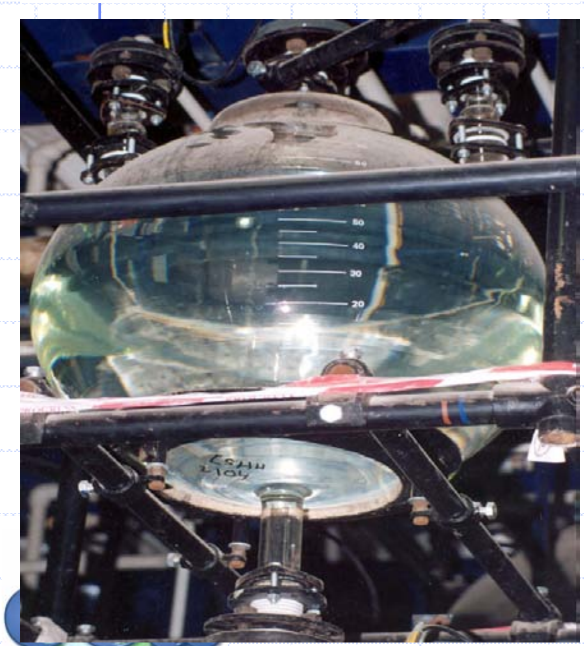
- The presence of a partially filled d sublevels in a transition element results in colored compounds.
- Elements with completely full or completely empty subshells are colorless,
  - For example Zinc which has a full d subshell.   Its compounds are white
- A transition metal ion exhibits color, if it absorbs light in the visible range (400-700 nanometers)
- If the compound absorbs a particular wavelengths of light its color is the composite of those wavelengths that it does not absorb.
- It shows the complimentary color.

Magnetic Properties



- Paramagnetism --- Molecules with one or more unpaired electrons are attracted to a magnetic field. The more unpaired electrons in the molecule the stronger the attraction. This type of behavior is called
- Diamagnetism --- Substances with no unpaired electrons are weakly repelled by a magnetic field.
- Transition metal complexes with unpaired electrons exhibit simple paramagnetism.
- The degree of paramagnetism depends on the number of unpaired electrons

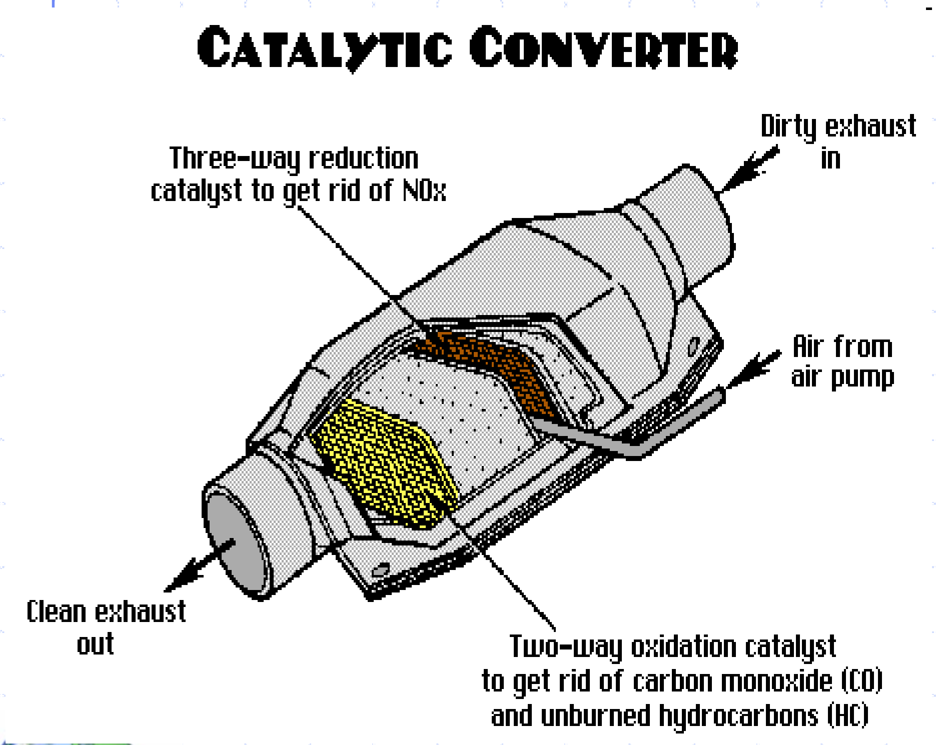
Catalytic Behavior



- Many D block elements are catalysts for various reactions
- Catalysts speed up the rate of a chemical reaction with out being consumed.
- The transition metals form complex ions with species that can donate lone pairs of electrons.
- This results in close contact between the metal ion and the ligand.
- Transition metals also have a wide variety of oxidation states so they gain and lose electrons in redox reactions

Some Common D-Block Catalysts

- Examples of D block elements that are used as catalysts:

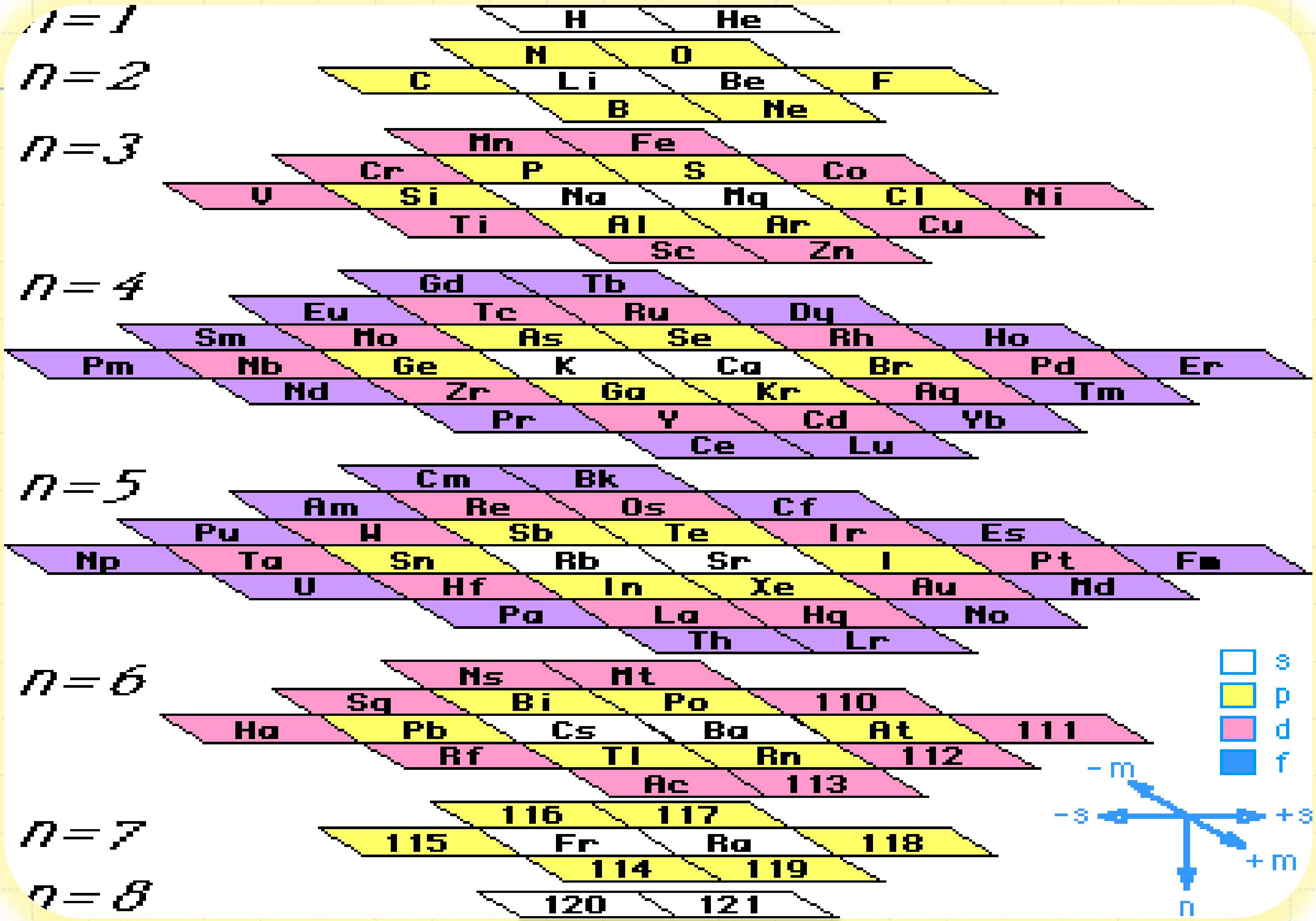


1. Platnium or rhodium is used in a catalytic converter
2. MnO_2 catalyzes the decomposition of hydrogen peroxide
3. V_2O_5 is a catalyst for the contact process
4. Fe in Haber process
5. Ni in conversion of alkenes to alkanes

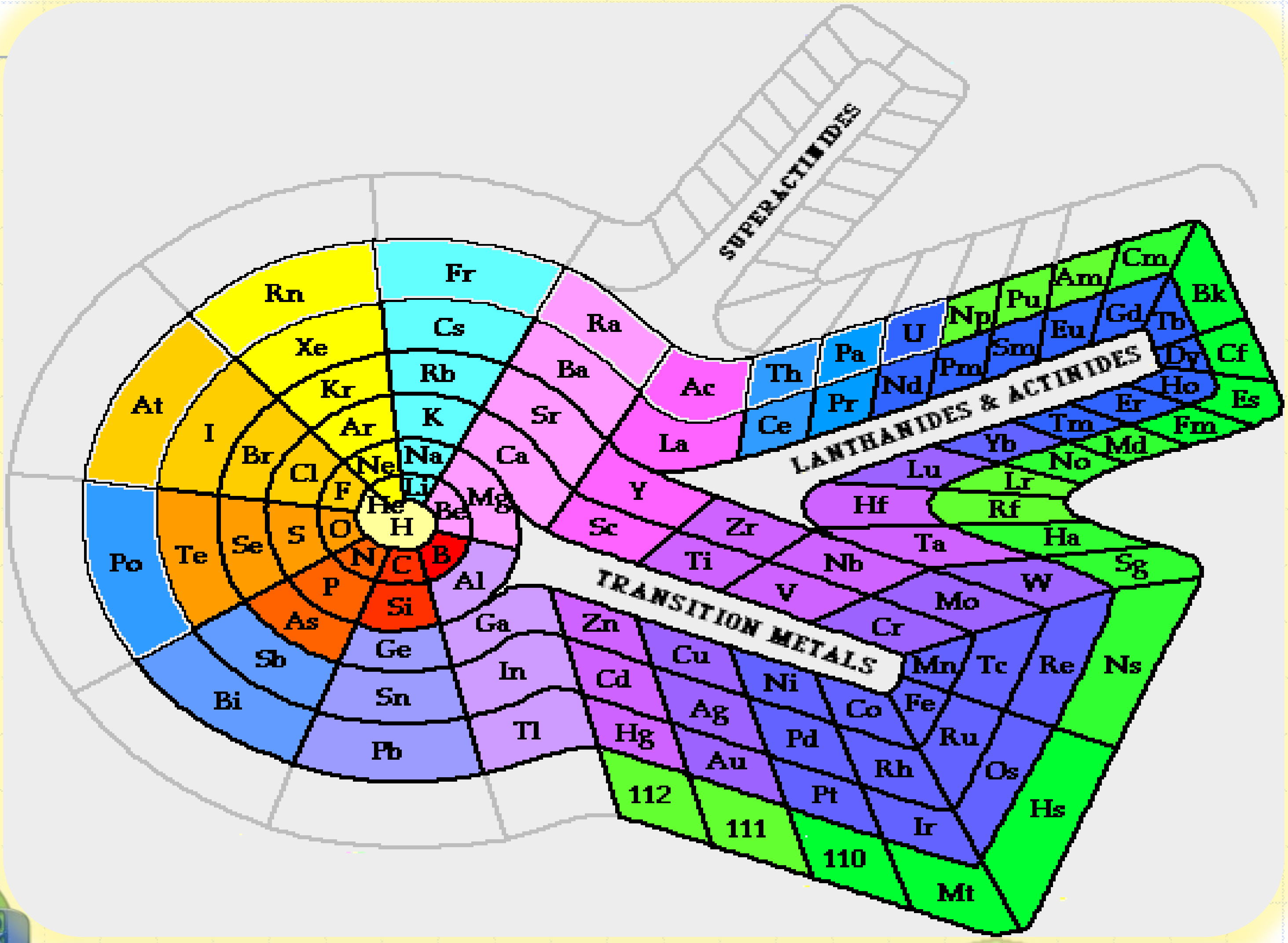
Alternate Periodic Tables

Although we are most familiar with the periodic table that Seaborg proposed more than 60 years ago, several alternate designs have been proposed.

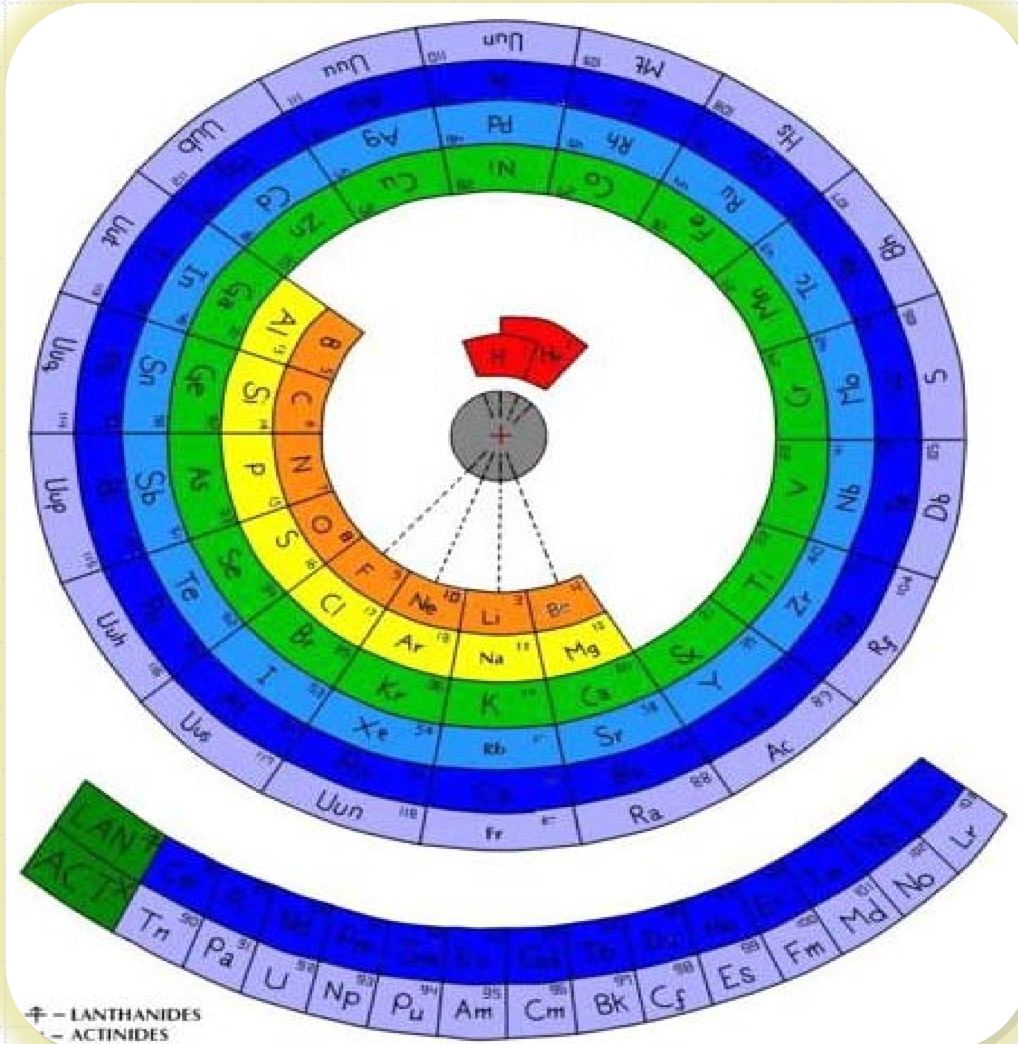
Alternate Periodic Tables



Alternate Periodic Tables II



Alternate Periodic Tables III



Alternate Periodic Tables IV